PATHFINDER

CARGO VEHICLE PROPULSION PROGRAM PLAN

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PROJECT PATHFINDER

PATHFINDER CARGO VEHICLE PROPULSION PROGRAM PLAN

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FOREWORD

Pathfinder is a research and technology initiative by the National Aeronautics and Space Administration (NASA) which will strengthen the technology base of the United States civil space program and provide options for potential future space exploration missions. These missions may include an intensive study of the Earth, a return to the Moon, piloted missions to Mars, or the continuing robotic exploration of the Solar System. Pathfinder is managed by the NASA Office of Aeronautics and Space Technology, to advance critical technologies for these missions and ensure technology readiness for future national decisions regarding exploration of the Solar System. Pathfinder extends the technological foundation being established by the Civil Space Technology Initiative, which focuses on advancing a family of technologies for transportation to and operations in near-Earth orbit and supporting science activities. Pathfinder looks toward longer-term missions beyond Earth orbit and into the Solar System.

Four major thrusts of Pathfinder are Surface Exploration technology, In-Space Operations technology, Humans-in-Space technology, and Space Transfer technology. The Space Transfer thrust will provide the critical technologies needed for transportation to, and return from, the Moon, Mars and other planets in the Solar System, as well as for reliable and cost-effective Earth-orbit operations. A key element of this thrust is the Cargo Vehicle Propulsion Program which will develop advanced electric propulsion systems, focusing on magnetoplasmadynamic thruster component technologies, ion thrusters, and life testing of alternative electric propulsion options.

This Program Plan describes the goals and objectives, management plan, technical approach, resources and financial management plan, facilities plan and technology transfer planning for the Cargo Vehicle Propulsion element of Pathfinder. For additional information on the Cargo Vehicle Propulsion Program, please contact:

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SECTION 1

EXECUTIVE SUMMARY

1.1 Program Goals and Objectives

The Pathfinder High Performance Cargo Vehicle Propulsion Program will establish the feasibility and practicality of electric propulsion for piloted and robotic solar system exploration. The performance objectives are high specific impulse (over 4000 s), high efficiency (over 0.60), and low specific mass (less than 10 kg/kW), scalable to multi-megawatt power levels. Sufficient durability will be targeted to enable total impulses on the order of 10^8 to 10^9 N-s per engine.

1.2 Organization and Management

The High Performance Cargo Vehicle Propulsion Program will be managed at OAST by the Propulsion, Power, and Energy Division. Lewis Research Center (LeRC) will act as Lead Center for the program, with responsibility for technical integration and reporting; this function will be performed by the Low Thrust Propulsion Branch. The work will be performed by LeRC and the Jet Propulsion Laboratory (JPL). A preliminary version of this management structure is provided in Figure 1-1.

1.3 Schedules and Deliverables

The High Performance Cargo Vehicle Propulsion Program will concentrate on performance and critical feasibility issues for the candidate thrusters. It is assumed that the low specific mass megawatt power subsystem required will be available from other National programs; therefore, this development effort is not included herein. The first step will be to assess facility impacts on the fidelity of performance and durability data. Reliable short-term, in-situ methods of evaluating life issues will be developed along with the required facility capabilities, so that performance limits can be established for each type of thruster. Parallel thruster technology efforts will be performed for both self-field and applied-field MPD thrusters as well as ion engines. It is necessary to devote most of the resources early in the program to MPD technology development, because of its much greater technical uncertainities. Power processor technology will be directed to provide laboratory-class hardware. Supporting thermal and system analyses will be included in the program, while mission studies will be provided from outside sources. By the mid-1990's the most promising candidate thruster will be selected for further development, and the definition of system and facility requirements for megawatt-class thruster development completed.

1.4 Resources

Approved resources for the initial five years of the program are summarized in Table 1-1.

TABLE 1-1. -- HIGH PERFORMANCE CARGO VEHICLE PROPULSION 5-YEAR (PHASE I) CYCLE RESOURCE ALLOCATION

RESOURCE ALLOCATION	FY 89	FY 90	FY 91	FY 92	FY 93	FY 94
FUNDING, M$	0.0	2.0	4.0	5.0	5.0	6.0
NASA WK-YRS	0.0	3.0	3.0	4.0	4.0	4.0

CARGO VEHICLE PROPULSION MANAGEMENT STRUCTURE

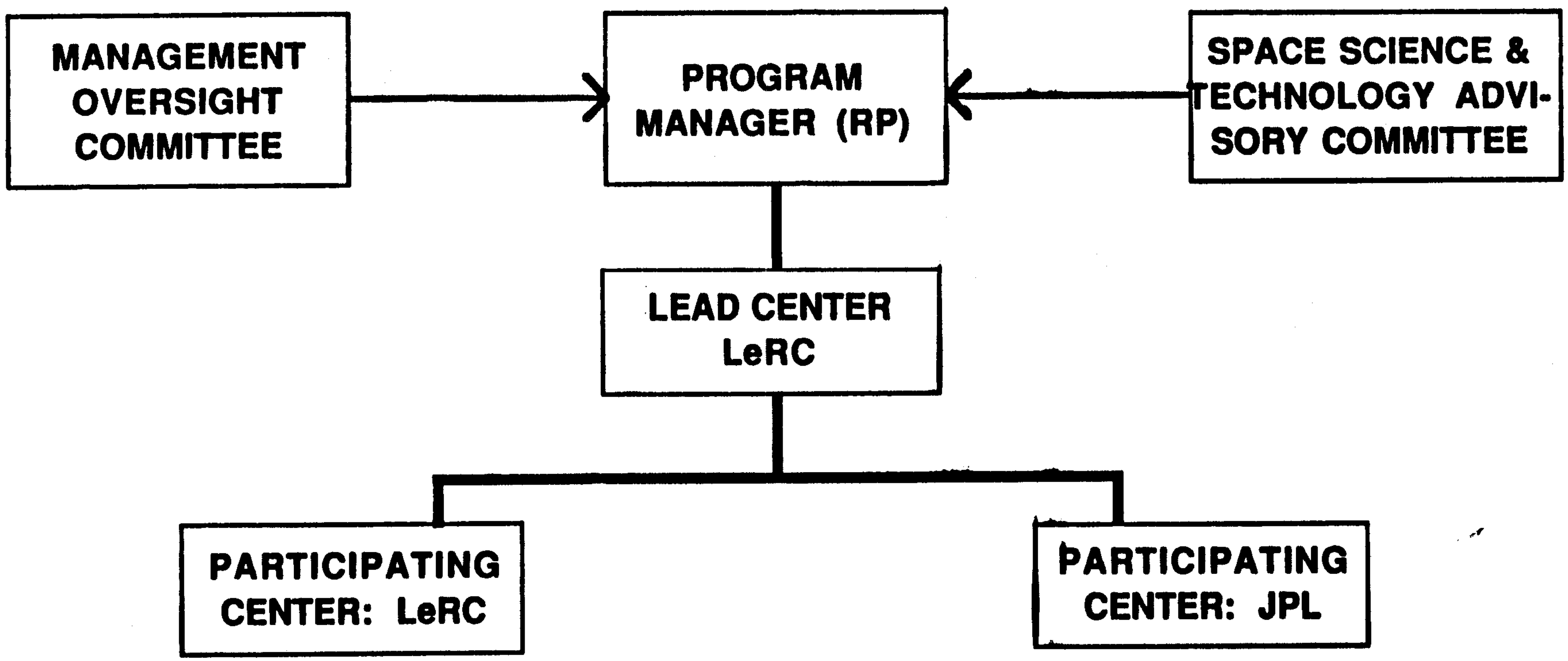

Figure 1-1

SECTION 2

INTRODUCTION

2.1 Project Pathfinder Overview

Project Pathfinder is a National Aeronautics and Space Administration (NASA) initiative to develop critical capabilities to support the future of the U.S. civil space program. Pathfinder does not, in itself, represent a commitment to any particular mission. However, through Pathfinder, NASA's Office of Aeronautics and Space Technology (OAST) will develop a variety of high-leverage technologies that can be applied to a wide range of potential future NASA programmatic thrusts: (1) surface exploration, (2) in-space operations, (3) humans-in-space, and (4) space transfer.

The Cargo Vehicle Propulsion Program is one of three programs under the Space Transfer thrust. More information on the overall Pathfinder Program can be found in the Pathfinder Program Plan.

2.2 Document Purpose and Scope

The goal of this Program Plan is to provide scope, content, and long-range plans of the Cargo Vehicle Propulsion Program. The Objectives of this document vis-a-vis the Program are (1) to provide traceability to mission-derived technology requirements; (2) to specify the top-level work breakdown structure; (3) to define technical goals and objectives for the program and for major workpackages; (4) to define the management approach (including structure, participating centers and individual roles, responsibilities, and accountability; (5) to establish reserve allocations, and associated schedules, milestones, and deliverables; and (6) to document long-range Cargo Vehicle Propulsion program planning.

A three-phase program is envisioned. Phase I will cover five years devoted to establishing feasibility and practicality and will culminate in the selection of the most promising concept for further development. Phase II will be a five-year focused technology program which will demonstrate performance and life at high power and define flight test requirements. Phase III will provide the required flight validation of high performance, high power electric propulsion technology.

The High Performance Cargo Vehicle Propulsion Program will concentrate on performance and critical feasibility issues for the candidate thrusters. It is assumed that the low specific mass megawatt power subsystem required will be available from other programs; therefore, this development effort is not included herein. The first step will be to assess facility impacts on the fidelity of performance and durability data. Reliable short-term, in-situ methods of evaluating life issues will be developed along with the required facility capabilities, so that performance limits can be established for each thruster. Parallel thruster technology efforts will be performed for both self-field and applied-field MPD as well as ion engines. It is necessary to devote most of the resources early in the program to MPD technology advancement, because of its much greater technical uncertainities. Power processor technology will be directed to provide laboratory-class hardware. Supporting thermal analyses and systems definitions will be included in the progam, while mission studies will be provided from outside sources.

SECTION 3

PROGRAM OVERVIEW

3.1 Mission Studies and Technology Requirements

The cost of placing any spacecraft in low Earth orbit (LEO) is a major fraction of the mission cost, and propellant is becoming the dominant mass for many spacecraft using chemical propulsion. For example, on the Galileo mission, propellant accounts for 43 percent of the total mass, and for the more challenging Comet Rendezvous Asteroid Flyby (CRAF) mission, the propellant fraction is 76 percent (Ref. 1).

More challenging missions, such as those to the Moon and Mars, will place even greater demands on propulsion. Studies have shown that for a Mars cargo vehicle large enough to support a manned mission, high performance electric propulsion with specific impulses over 4000 s at multi-megawatt power levels can offer major reductions in propellant requirements at acceptable transit times. Compared with an aerobraking cargo vehicle using hydrogen/oxygen propulsion, a non-aerobraking high performance electric vehicle can result in elimination of at least three Heavy Lift Launch Vehicle (HLLV) launches, and savings are even greater when compared with non-aerobraking chemical propulsion (Ref. 2). This reduction in the number of launches might permit the mission to be completed more rapidly if HLLV launch rates are low.

High specific impulse clearly offers propellant mass savings, but in order to practically exploit that benefit for space missions, it is necessary for the overall vehicle to exhibit acceleration levels sufficient to meet mission time lines. This requirement necessitates low specific mass and high efficiency propulsion and power systems in order to keep power system mass low. High total impulse and high power per engine are also needed to permit the missions to be accomplished with an acceptable number of engines.

Electric propulsion is also applicable to advanced robotic exploration missions, offering both decreased propellant mass (and/or increased payload) and reduced trip times for deep space missions. Furthermore, this technology may be applicable to manned spacecraft using artificial gravity, where speed is not so critical.

3.2 Technology Assessment

At present, the only operational uses of electric propulsion are low power systems used to perform satellite stationkeeping. Since specific impulses (I_{sp}) over 4000 s are of interest for Pathfinder (Ref. 2), electrothermal systems such as arcjets are not adequate even with hydrogen propellant (I_{sp}< 1500 s). Advanced concepts, such as electrodeless thruster systems, may ultimately provide the desired characteristics, but do not have sufficient technical maturity to be considered in the Pathfinder time frame. The two concepts of interest for this program are electrostatic (ion) and magnetoplasmadynamic (MPD) engines.

Ion engines have demonstrated specific impulses from less than 2000 s to more than 10,000 s, thrust efficiencies to over 0.75, and total thrust impulse as high as 10^6 N-s for 10-kW class thrusters. Key issues are scale-up of ion acceleration subsystems for high power operation and thruster life.

MPD propulsion is less advanced than ion. Power levels of 5 MW have been demonstrated in a pulsed mode, but only about 250 kW for steady power. Most of the efficiency data fall in the 0.15 to 0.35 range, although some data for hydrogen and lithium propellants approach 0.5 at very low power. Higher efficiencies and specific impulses are generally obtained with applied magnetic fields, but the fundamental theoretical understanding of this mode of operation is lacking. The highest total impulse demonstrated is 10^6 N-s, at about 25 kW (Ref. 3).

Facility background gas composition and pressure have been shown in some cases to have very significant impacts on measured performance, as much as a factor of 2, and life. The impact of facility effects and the availability of high-fidelity ground test facilities are serious issues.

3.3 Cargo Vehicle Propulsion Program Goals and Objectives

The goal of this program is to develop the technology for high performance, high power, electric propulsion systems which could substantially reduce the mass required in low Earth orbit (LEO) for the manned Mars mission's cargo vehicle and other future agency missions requiring large planetary vehicles.

Program objectives include:

(1) Development of high specific impulse (over 4000 s), high efficiency (over 0.60), and low specific mass (less than 10 kg/kW), electric propulsion systems scalable to multi-megawatt power levels, with sufficient durability to enable total impulse on the order of 10^8 to 10^9 N-s per engine. Phase I will cover five years devoted to establishing feasibility and practicality and will culminate in the selection of the most promising concept for further development.

(2) Demonstration of performance and life at high power and definition of flight test requirements in the Phase II, five-year focused technology program .

(3) Flight validation, if required,in Phase III.

3.4 Technical Approach

The High Performance Cargo Vehicle Propulsion Program will concentrate on performance and critical feasibility issues for the candidate thrusters. It is assumed that the low specific mass megawatt power subsystem required will be available from other programs; therefore, this development effort is not included herein. The first step will be to assess facility impacts on the fidelity of performance and durability data. Reliable short-term, in-situ methods of evaluating life issues will be developed along with the required facility capabilities, so that performance limits can be established for each thruster. Parallel thruster technology efforts will be performed for both self-field and applied-field MPD as well as ion engines. It is necessary to devote most of the resources early in the program to MPD technology advancement, because of its much greater technical uncertainities. Power processor technology will be directed to provide laboratory-class hardware. Supporting thermal and analyses will be included in the progam, while mission studies will be provided from outside sources.

SECTION 4

MANAGEMENT PLAN

4.1 Work Breakdown Structure

The High Performance Cargo Vehicle Propulsion Program is divided into seven major work elements: (1) facilities, (2) self-field MPD thrusters, (3) applied-field MPD thrusters, (4) ion thrusters, (5) power processors, (6) thermal analyses, and (7) systems definitions. Figure 4-1 shows the Work Breakdown Structure (WBS) for Phase I.

4.2 Organization and Management Structure

The High Performance Cargo Vehicle Propulsion Program will be managed at OAST by the Propulsion, Power, and Energy Division, with the support of an advisory steering group with members from the OAST Space Systems Directorate and technical divisions, the Office of Exploration (OEXP), and the Office of Space Science and Applications (OSSA). Lewis Research Center (LeRC) will act as Lead Center for the program, with responsibility for technical integration and reporting; this function will be performed by the Low Thrust Propulsion Branch. The work will be performed by LeRC and the Jet Propulsion Laboratory (JPL). A preliminary version of the management structure is provided in Figure 1-1.

4.3 Program Coordination

The work will be coordinated with related national programs such as the NASA Pathfinder and Civil Space Technology Initiative (CSTI) power programs and the high power programs sponsored by the Strategic Defense Initiative Organization (SDIO) and the Department of Energy (DOE). The program will be technically supported by and coordinated with mission studies conducted by the LeRC Advanced Systems Analysis Office (ASAO) for OEXP and planetary mission studies conducted by the Advanced System

Analysis Group at JPL for OSSA. As appropriate, specific mission studies or opportunities for mission enhancements through applications of high performance propulsion technology will be recommended to those offices.

4.4 Program Documentation and Planning

Resources will be distributed to the Centers from the Pathfinder Program by means of RTOP's which are, in turn, related the plans and objectives of the PASO document. Therefore, the Centers will be required to provide a cross reference between the Center budget distributions in the Project Plans and the proposed Center RTOP guidelines. The Cargo Vehicle Propulsion Program Element Manager will specify plans for the Headquarters resources and the reserves that will be retained in the Element budget line. Since the Element and Project Plans form the "contracts" between the Pathfinder Program Manager, the Element Program Manager, and the Project Manager, the RTOP is simply a funding transfer and tracking instrument for the program, and only minimal program information is required in the RTOP.

4.4.1 Cargo Vehicle Propulsion Project Plan

A detailed five-year project plan (with less detailed extensions to ten years) is being developed. The LeRC Project Manager will be responsible for developing and implementing this plan. The Project Manager will coordinate the planning activities with JPL and OAST. The project plan will document program content, center responsibilities, resource allocations, and milestones. Both centers will participate in project reviews held twice each year. The project plan will be modified as required.

4.4.2 Memoranda of Understanding (MOU's)

Since the program will be fully funded and carried out by the OAST Propulsion, Power, and Energy Division, no Memoranda of Understanding are required.

4.5 Program Reviews and Reporting

The LeRC Project Manager will conduct periodic reviews with the Program Manager. These reviews will include reporting on progress toward key milestones and will assure that OAST is informed as to program status including resource expenditures and requirements for both LeRC and JPL. (JPL will provide the LeRC Project Manager with the information on the JPL portion of the program.) These reviews will be held a minimum of twice each year.

4.5.1 Monthly Reports

Monthly reporting will be required only on a meeting/memo/ presentation basis to the Cargo Vehicle Propulsion Program Manager; that reporting will be provided in a standard format through half-day monthly Headquarters review/ discussions of the Pathfinder Program. (Note: this monthly status reporting review will be held approximately one week before the monthly General Management Status Review (GMSR) and thus will be part of the normal OAST reporting process.)

4.5.2 Quarterly Reports

The quarterly report submitted by the lead center (LeRC), subject to approval by the Cargo Vehicle Propulsion Program Manager, will be submitted to the Pathfinder Program Manager. These reports will be provided by the first of the month following the completion of the quarter. These reports will cover technical progress and program status including resource expenditures and requirements for both LeRC and JPL. (JPL will provide the LeRC Project Manager with the information on the JPL portion of the program.) .

4.5.3 Annual Reports

No formal annual report is required; however, the final quarterly report with additional information as requested will serve as an annual report. The program will also be reviewed in the annual center review.

4.5.4 Milestone Reports

The LeRC Project Manager will provide special topical reports to the Cargo Vehicle Propulsion Program Manager when key milestones have been achieved.

4.6 Advisory Committees and Working Groups

The High Performance Cargo Vehicle Propulsion Program will be conducted with the support of an advisory steering group with members from the OAST Space Systems Directorate and technical divisions, the Office of Exploration (OEXP), and the Office of Space Science and Applications (OSSA).

CARGO VEHICLE PROPULSION WORK BREAKDOWN STRUCTURE

OAST

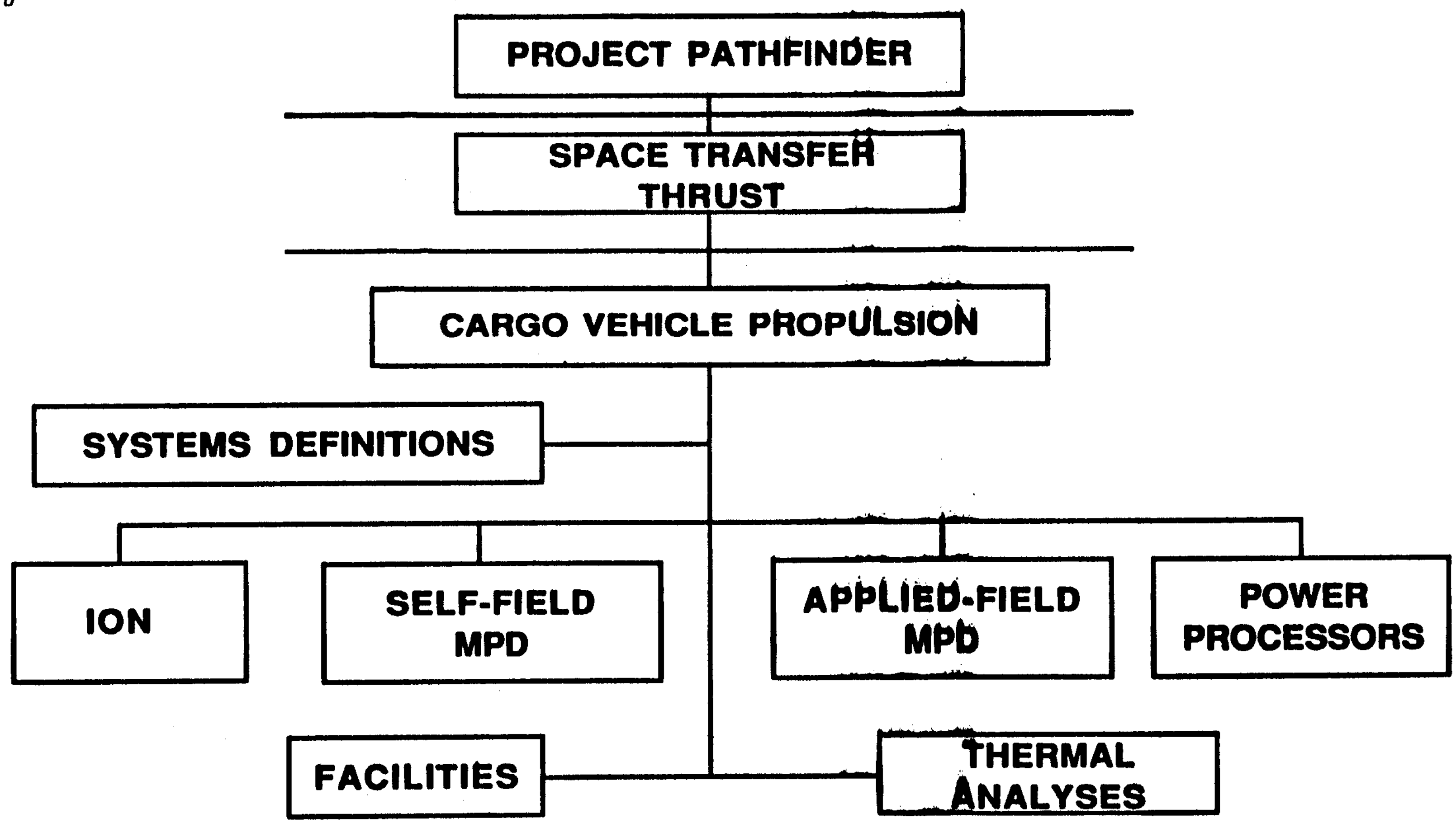

Figure 4-1

SECTION 5

TECHNICAL PLAN

5.1 Summary of Deliverables

By the mid-1990's the feasibility and practicality of megawatt-class electric propulsion will be determined and the most promising concept selected for focused development in Phase II, and system and facility requirements will be established.

5.1.1 Five Year Schedule and Milestones

Figure 5-1 provides a top-level schedule for the 5 year Phase I program. Milestones for the program are shown in Table 5-1.

5.1.2 Technology Readiness Objectives

Table 5-2 indicates the technology level assessed at this point in the program and the target levels to be reached in this program.

5.1.3 Technology Performance Objectives

Technology performance goals will be developed and updated with the support of an advisory steering group with members from the OAST Space Systems Directorate and technical divisions, the Office of Exploration (OEXP), and the Office of Space Science and Applications (OSSA). Current objectives, appropriate for present Mars cargo vehicle concepts and other challenging missions are as follows:

(1) High specific impulse (over 4000 s),

(2) High efficiency (over 0.60),

(3) Low specific mass (less than 10 kg/kW),

(4) Scalability to multi-megawatt power levels,

(5) Sufficient durability to enable total impulse on the order of 10^8 to 10^9 N-s.

5.2 Self-Field MPD Thrusters

5.2.1 Objectives

The major objective is to demonstrate the feasibility of the required thruster efficiencies with an acceptable propellant Also, definition of the relationship between MPD thruster characteristics and limits in pulsed and steady state operation must be achieved. Definition of thruster designs which have promise of meeting the total impulse requirements of lunar and Mars missions is essential. Specific objectives for the self-field concept are as follows:

(1) MPD thruster efficiency of greater than 0.6 at specific impulses over 4000 s with an acceptable propellant.

(2) Definition of scaling relationships between pulsed and steady state operation as a function of power,

(3) Thruster lifetime feasibility demonstrations to greater than 10^8 N-s total impulse.

(4) Scalability to multi-megawatt power levels,

5.2.2 Technical Approach

Experiments initiated at a low level in the Base R&T program will be accelerated and focused toward higher power. Initially, experiments will be conducted in a pulsed mode with a variety of propellants. Thruster optimizations will be conducted to define the limits of operation and performance for self-field MPD thrusters. Steady state testing will be conducted to allow correlation of pulsed and steady state thruster characteristics as a function of run mode and power level. Fundamental analyses and experiments will be conducted to provide insight into basic mechanisms of operation.

5.3 Applied-Field MPD Thruster

5.3.1 Objectives

The major objective is to determine the performance and practicality of MPD thruster operation with applied magnetic fields with acceptable propellants. The relationship between self- and applied-field thrusters will be defined as a function of power level and operating modes. A theoretical basis for operation with an applied field will be established, and thruster concepts will be defined and verified with promise of meeting the total impulse requirements of lunar and Mars missions, as follows:

(1) MPD thruster efficiencies of greater than 0.6 at specific impulses over 4000 s with an acceptable propellant,

(2) Theoretical model for applied-field MPD operation along with magnet power and thermal requirements,

(3) Establish feasibility of thruster total impulse capability greater than 10^8 N-s,

(4) Scalability to multi-megawatt power levels.

5.3.2 Technical Approach

Sub- and multi-Tesla magnetic fields will be applied to MPD thrusters in steady state operation, and the impacts on thruster characteristics and limits established. Direct measurements of the lifetimes of the anodes and cathodes will be made as a function of the operating conditions and propellant. Analyses will be performed to establish the theoretical understanding of the effects of high strength magnetic fields on MPD operation.

5.4 Ion Thrusters

5.4.1 Objectives

The major objective is to establish the feasibility of operation of ion thrusters at high levels of power and thrust at acceptable levels of specific impulse with acceptable propellants and with sufficient lifetime. Current objectives, appropriate for lunar and Mars cargo vehicle concepts are as follows:

(1) Efficiencies over 0.6 at specific impulses over 4000 s,

(2) Feasibility of thruster power level greater than 0.75 MW,

(3) Thruster lifetimes required by lunar and Mars missions with total impulses of at least 10^8 N-s.

5.4.2 Technical Approach

Scaling relations and manufacturing methods will be investigated to provide large, stable, possibly non-circular ion acceleration subsystems which can operate at high current density with low applied voltage. To enable long-life, high-power thrusters, fundamental experiments will be conducted to provide an understanding of life-controlling mechanisms whose rates are nonlinear functions of power density. Phase I will focus on scale-up of the ion acceleration subsystem (optics) and on fundamental studies of life limiting processes.

5.5 Power Processors

Laboratory-class power processors will be tested in support of thruster research. This experience will define the critical component technologies required for full scale power processors. Studies will be conducted in order to define the mass, efficiency, and costs of power processing for full scale systems as a function of thruster type and power level. Focused development of both high power components and circuits will not start until Phase II, when the propulsion concept has been selected.

5.6 Thermal Analyses

Thermal control activities will be limited to studies in Phase I. The major objective of these studies will be to define the optimum cooling concept (radiation and/or cooling loops) on a system level and to quantify the mass and other requirements of various cooling system approaches.

5.7 System Definition

System definition activities will be limited to studies in Phase I, with more intese effort delayed until after propulsion concept selection.

TABLE 5-1 -- HIGH PERFORMANCE CARGO VEHICLE PROPULSION PROGRAM MILESTONES

DATE	MILESTONE
FY90	COMPLETE HIGH-FIDELITY 250-kW_e ELECTRIC PROPULSION FACILITY.
FY90	COMPLETE MISSION APPLICATION STUDIES.
FY91	DEMONSTRATE 1000-HR LIFE FOR 50-kW_e ION THRUSTER.
FY91	IOC FOR 0.5-MW_e FACILITY.
FY92	SELECTION OF MDP CATHODE MATERIAL AND DESIGN.
FY92	EXPERIMENTALLY DETERMINE PERFORMANCE OF TESLA-CLASS MAGNETIC NOZZLE (MPD).
FY92	ESTABLISH PERFORMANCE LIMITS FOR 0.5-MW_e SELF-FIELD MPD THRUSTER.

TABLE 5-1 -- HIGH PERFORMANCE CARGO VEHICLE PROPULSION PROGRAM MILESTONES (CONCLUDED)

DATE	MILESTONE
FY92	ESTABLISH PERFORMANCE LIMITS FOR 2-m (EQUIV. DIAM.) ION OPTICS.
FY93	ESTABLISH PERFORMANCE LIMITS FOR 0.5-MW_e APPLIED-FIELD MPD THRUSTER.
FY93	DEMONSTRATE 1000-HR LIFE FOR O.5-MW_e SELF-FIELD MPD THRUSTER.
FY94	DEMONSTRATE 1000-HR LIFE FOR O.5-MW_e APPLIED-FIELD MPD THRUSTER.
FY94	DEMONSTRATE 1000-HR LIFE FOR O.5-MW_e ION THRUSTER.
FY94	SELECT CONCEPT FOR FOCUSED DEVELOPMENT.
FY94	COMPLETE DEFINITION OF MEGAWATT-CLASS FACILITY REQUIREMENTS.
FY95	COMPLETE QUALIFICATION LIFE TESTING FOR SELECTED THRUSTER.
FY00	ESTABLISH TECHNOLOGY READINESS FOR MISSION SYSTEM DEVELOPMENT.

TABLE 5-2 – TECHNOLOGY READINESS LEVELS

DELIVERABLE	TECHNOLOGY READINESS LEVEL		
	CURRENT (1988)	PHASE I (1994)	PHASE II (2000)
SELF-FIELD MPD	3	5	–
APPLIED-FIELD MPD	3	5	–
ION	4	5	–
POWER PROCESSOR	3	5	–
THERMAL CONTROL	2	3	–
ELECTRIC PROPULSION SYSTEM	2	5	6

PROJECT PATHFINDER
CARGO VEHICLE PROPULSION

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PROGRAM SCHEDULE/MILESTONES

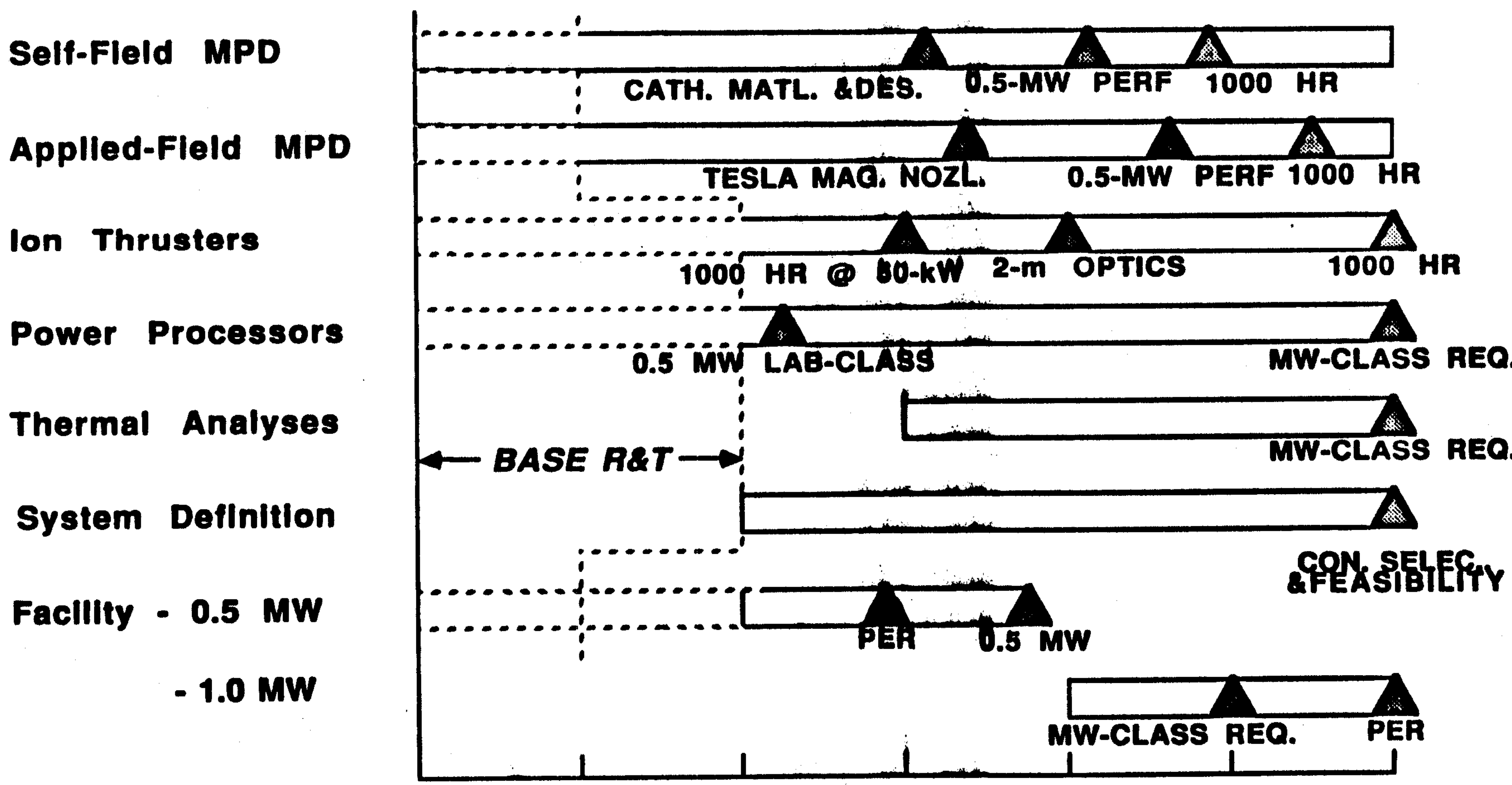

Figure 5-1

SECTION 6.0

RESOURCES AND FINANCIAL MANAGEMENT PLAN

Projected resource requirements for the program in terms of funding and civil service personnel are shown in Table 1-1.

6.1 Five-Year Funding Requirements

As shown in Table 1-1, projected funding requirements to meet the goals and objectives of the Cargo Vehicle Propulsion program for fiscal years 1989 through 1994 (Phase I) are approximately $20 million. There is no funding for FY 1989.

6.2 Five-Year Workforce Requirements

The current civil service staffing plan for the program is given in Table 1-1.

6.3 Contracting Plans

Although much of the research and development activities of this program will be conducted in government laboratories with available, high-fidelity facilities, there will be significant industry and university involvement.

Industry participation will begin in FY 1991 under the current funding plan.

University research will be an integral part of the Phase I program from the outset.

SECTION 7.0

FACILITY PLAN

7.1 Overview

Facility background gas composition and pressure have been shown in some cases to have very significant impacts on measured performance, as much as a factor of 2, and life. The impact of facility effects and the availability of high-fidelity ground test facilities are serious issues.

7.2 Facilities Assessment

Facilities at LeRC and JPL, as well as some university and industry facilities will be used. However, continuous testing at high power will require an upgrade of the large high-vacuum, high-throughput tanks at LeRC. The first step will be to assess facility impacts on the fidelity of performance and durability data. Reliable short-term, in-situ methods of evaluating life issues will be developed along with the required facility capabilities, so that performance limits can be established for each thruster.

7.3 Demonstration and Testing Facilities

Initial screening of performance and life will be done through subscale experiments in existing vacuum chambers. Establishment of full-scale performance and life will require a more capable facility with megawatt-level testing capabilities. In order to allow technology development and the selection of the most promising concept for full scale development in Phase II, a facility with moderately high power capability (0.5 MW class) and an adequate vacuum enviroment is needed in FY 1992. An even more capable facility will be needed in Phase II for extended testing at the megawatt level in an adequate vacuum enviroment.

SECTION 8.0

TECHNOLOGY TRANSFER PLANNING

8.1 Overview

The technology developed during the Cargo Vehicle Propulsion element of Pathfinder will be disseminated to the technical community through planned workshops, reviews publications and conference presentations. Industry and universities will be heavily involved early enough in the program to promote effective technology transfer.

APPENDIX A

References

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